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Activity Patterns of Small Terrestrial Vertebrates and Relationship to Coarse Woody Debris in Virginia Piedmont Forests

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ABSTRACT

Small mammals, reptiles, and amphibians were captured in mature hardwood-white pine forests in Franklin County, Virginia using drift fence-pitfall trap arrays from March to October for three years in plots with differing amounts of downed coarse woody debris (CWD). CWD plots included a control treatment with no manipulation of CWD, a treatment with total removal of CWD, and another with double normal amounts of CWD. A total of 3,637 captures of 38 vertebrate species (17 amphibians, 10 reptiles, and 11 mammals) was recorded during the three-year period. Captures were dominated by dispersing juvenile amphibians, particularly Green Frogs (*Lithobates clamitans*), which represented approximately 44% of captures. The number of captures was highest during the year with the highest rainfall and captures increased following rain events and on dates when average diel relative humidity was >80%. Captures did not vary significantly among the CWD treatments.

Key words: coarse woody debris, herpetofauna, small mammals, Virginia, wildlife.

INTRODUCTION

A large number of small terrestrial vertebrates, including small mammal, reptile, and amphibian species, occurs in Virginia forests. Although much is known about the natural history of the most common species, there is still limited information about many species regarding their relative abundance, seasonal activity, and relationship to habitat characteristics (Webster et al., 1985; Martof et al., 1989; Linzey, 1998; Mitchell & Reay, 1999). Such information is important for the conservation and management of forest biodiversity. Small vertebrate populations represent an important biotic component in forests because of their abundance and role in community and ecosystem processes. For example, they serve as a prey base for larger animals and may also be important predators of invertebrates and other vertebrates (Buckner, 1966; Burton & Likens, 1975). Small mammals are important dispersers of seeds and fungal spores, and play an important role in the turnover of organic matter (Stoddart, 1979). Many amphibian species are sensitive to environmental changes and are useful for monitoring ecosystem integrity (Welsh & Droege, 2001).

An important habitat element for small vertebrates is coarse woody debris (CWD). CWD consists of downed logs and trees, brush piles, stumps, and standing dead trees (snags) (Hagan & Grove, 1999). CWD is used by small terrestrial vertebrates for cover, nesting sites, refuge from predators, travel routes, and food sources (Wolff & Hurlbutt, 1982; Loeb, 1999; McCay, 2000). Forest biodiversity may be negatively impacted by management practices that decrease the amount of CWD (Loeb, 1999; MacNally et al., 2002).

Many studies have shown that there is a positive correlation between the abundance of small mammals and/or herpetofauna in forest stands and the amount of CWD (e.g., Barry & Francq, 1980; DeMaynadier & Hunter, 1995; McKay et al., 1998; Loeb, 1999; Menzel et al., 1999; McKenney et al., 2006; Shively et al., 2006), although see Bowman et al. (2000). Fewer studies, however, have directly involved the manipulation of CWD quantity, which is important for controlling confounding factors. Multi-year studies were conducted on the response of herpetofauna (Owens et al., 2008) and shrews (Moseley et al., 2008)

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to CWD manipulation in southeastern pine forests in the Coastal Plain of the southeastern United States. Few differences were found among treatments and it was suggested that low levels of CWD in these forests as a result of periodic fires may have resulted in reduced dependence on CWD. Rather, it was thought that many species in this region rely on burrowing under litter and into sandy soil in the absence of CWD. McCay & Komoroski (2003) also found that shrews had a weak response to the removal of CWD from managed pine forests compared to seasonal and inter-annual variations in abundance. In a study involving fuel reduction treatments in Appalachian hardwood forests, Greenberg et al. (2006) also found that White-footed Mice (*Peromyscus leucopus*) did not preferentially use areas with more CWD.

The objectives of this study were to 1) examine seasonal and inter-annual patterns of activity in small vertebrates in Piedmont forests of Virginia and 2) compare the activity of small vertebrates in areas manipulated to create different levels of downed CWD.

METHODS

Study Site and Experimental Design

The study was conducted on two different forested sites at Ferrum College in Ferrum, Virginia (Moonshine Creek and Chapman Pond) and another forested site located approximately 1 km from the College (Nicholas Creek). The three sites were considered as blocks in this experiment. In fall 2004 and spring 2005, three adjacent 50 x 50 m plots were established within each block with a 10 m buffer zone between the plots. The plots within each block were oriented parallel to a small stream to avoid bias among the plots with respect to distance to the stream. For two blocks, the distance from the stream to the nearest edge of the plots was ca. 30 m. For the third block, the stream was located just inside one border of the plots. The three plots within each block were similar with respect to tree species composition, aspect slope position, and amount of woody debris. The dominant tree species included White Pine (*Pinus strobus*), Tuliptree (*Liriodendron tulipifera*), Red Maple (*Acer rubrum)*, and oaks (*Quercus* spp.). Slopes ranged from 1-3%. The three plots at each site were randomly assigned to one of three treatments: (1) no treatment (control plot), (2) all woody debris removed from the plot, or (3) amount of woody debris doubled (added all woody debris from removal plot). The treatments are hereafter designated as 1X, 0X, and 2X. In moving CWD from the 0X to the 2X treatments, heavy or long pieces were sometimes cut into segments to facilitate transport. The pieces were evenly dispersed among the 2X treatment plots.

CWD in this experiment was defined as any stem or branch, of any length, on the forest floor that has a diameter greater than 5 cm. Small vertebrates typically do not use fallen CWD with a diameter less than 5 cm for cover, nesting areas, or travel routes (Barnum et al., 1992). The amount of woody debris in each plot was estimated in the early spring of 2007 by measuring the midpoint diameter and length of all logs within a 10 x 10 m subplot in the middle of each plot. Woody debris volumes on 1X plots ranged from 57.4-238.0 m^3/ha (mean = 148.76) and volumes on 2X plots ranged from 369.0–483.9 m^3/ha (mean = 411.6).

A drift fence-pitfall array in the shape of a "+" was established in the center of each treatment plot to capture small vertebrates, particularly small mammals, amphibians, and reptiles. At the center of each array, a 20-l plastic bucket was buried so that its rim was flush with the ground surface. Five-meter segments of woven plastic silt fence, supported by wooden stakes and partially buried in the ground, extended out from the central bucket in the four cardinal directions. At the end of each drift fence segment, another bucket was installed in the ground. The lid of the bucket was supported by wooden stakes approximately 25 cm above the bucket to reduce rainfall entry and provide shade for captured animals. Holes were drilled in the bottom of the buckets to facilitate water drainage.

Sampling

Preliminary trapping was conducted sporadically in all blocks during 2005, but data were not recorded in order to allow time for animal populations to respond to the treatments. Data collection began in March 2006 and continued until late September or early October for three consecutive years. Pitfall traps were checked daily with the exception of a two-week period in May 2007 and a one-week period in June 2008, when the traps were closed temporarily due to lack of personnel. There was a total of 3,100 trap-nights per treatment plot (5 traps x 219, 202, and 199 nights in 2006, 2007, and 2008, respectively). Captured vertebrates were identified and the number of individuals of each species was recorded. Animals were released unmarked outside of and facing away from the pitfall trapping area. Incidentally captured invertebrates were also removed from the traps.

After observing that a large number of captures tended to occur the day of or following rainfall during 2006, one Hygrochron® relative humidity sensor (Thermochron Corporation, Dallas TX) was placed at each site on the forest floor near the middle of each central treatment plot during 2007 and 2008. The sensors were programmed to record relative humidity measurements at 30-minute intervals.

Data Analysis

The number of captures was summed by year, block, and treatment. A randomized complete block design ANOVA was conducted using SYSTAT 12.2 (SYSTAT Software, Inc., San Jose, CA) to test for differences among year and treatment effects for all captures, captures by taxonomic group (amphibian, reptile, mammal), and captures by species. The number of captures was transformed using the natural logarithm of captures to correct for deviations from the normal distribution as well as heterogeneous variance among sampling years and CWD treatments.

RESULTS

A total of 3,637 captures of 38 vertebrate species (17 amphibians, 10 reptiles, and 11 mammals) was recorded during the three-year study period (Table 1). A much larger number of captures (2,108) occurred in 2006 as compared to 2007 (794) and 2008 (735). On a per trap-night basis, captures were also higher in 2006 (0.21) than 2007 (0.09) or 2008 (0.08). The much higher number of captures in 2006 was due primarily to a nearly 10-fold higher number of Green Frog (*Lithobates clamitans*) captures (1,195 in 2006 vs. 199 in 2007 and 194 in 2008). Several other amphibian species also had approximately twice the number of captures in 2006 as compared to other years, including Red-spotted Newt (*Notophthalmus viridescens*), Pickerel Frog (*Lithobates palustris*), and American Toad (*Anaxyrus americanus*).

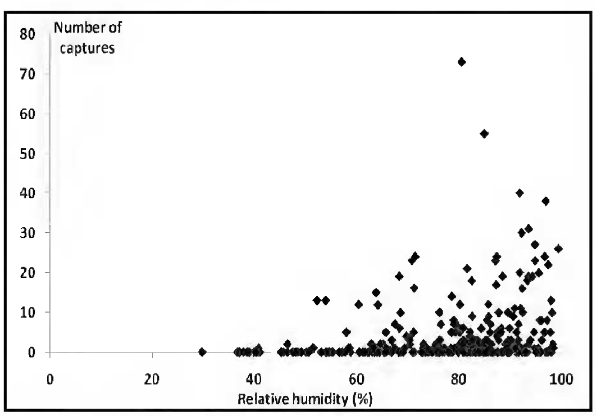

Fig. 1. Relationship between the number of daily pitfall trap captures and average relative humidity from March-September 2007-2008 at three forest locations in Franklin County, Virginia.

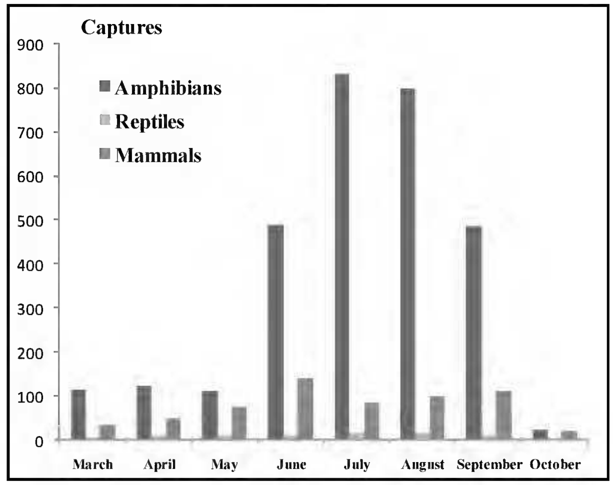

Fig. 2. Total captures of vertebrates from March-October 2006-2008 in pitfall traps at three forest locations in Franklin County, Virginia. Note that traps were only open for a few days in October during 2006 and 2007 and not open during October 2008.

Live and dead captures were not distinguished in 2006, but in 2007 and 2008, 76.5% and 76.7% of all captures were live, respectively. The number of captures tended to increase following rain events and highest number of captures occurred on dates when average diel relative humidity was > 80% (Fig. 1).

Year and CWD quantity did not significantly affect the number of small mammal captures (Table 1), although there was a strong trend towards higher numbers of captures for 2006 ($p = 0.054$). There was also no significant difference among CWD treatments for the three taxonomic groups (amphibians, reptiles, mammals) in this study (Table 2). For those species with a sufficient number of captures to merit statistical testing, there was also no difference among CWD treatments.

Amphibians represented 80.5% of total captures with small mammals and reptiles comprising 17.5% and 2%, respectively. A large proportion of the amphibian captures occurred from June to September (Fig. 2), corresponding with the dispersal of numerous recently metamorphosed juveniles, particularly those of the Green Frog, American Toad, and Red-spotted Newt. Among the rarer amphibian species captured was one Eastern Narrow-mouthed Toad (*Gastrophyrne carolinensis*), the first recorded for Franklin County.

Green Frogs were the most common species encountered in this study, representing 43.7% of all captures; nearly all were juveniles. Approximately 96% of the 1,588 green frogs captured during the study were from the Moonshine Creek site, which was located ca. 100 m from a small (0.1 ha) pond. Nearly all of the

Table 1. Analysis of variance table for total pitfall trap captures for year and coarse woody debris (CWD) treatments in three forest locations in Franklin County, Virginia. Data were transformed using the natural logarithm of captures. Differences are considered to be significantly different at $p \leq 0.05$.

Source	Sums of squares	Mean square	df	F ratio	P value
Year	3.416	1.708	2	3.456	0.054
Treatment	0.210	0.105	2	0.212	0.811
Year*Treatment	0.019	0.005	4	0.009	0.990
Error	8.895	0.494	18		

other green frogs were captured at the Chapman Pond site, ca. 100 m from the 0.25-ha Chapman Pond. More Green Frogs were captured in 2006 than in other years ($p = 0.002$). Location had a strong effect on the number of captures. Green Frogs were captured in significantly higher numbers at the Moonshine Creek site ($p < 0.001$) and Red-spotted Newts were captured in significantly higher numbers at the Chapman Pond site ($p < 0.001$). Green Frog captures peaked in July, while Red-Spotted Newt captures peaked later in the summer (Fig. 3).

Although ten species of reptiles were caught, their numbers were low. Reptiles were the least commonly captured (n = 80) type of vertebrates during the study (Table 2). The Five-lined Skink (*Plestiodon fasciatus*) was the most common reptile species captured (n =32), followed by the Wormsnake (*Carphophis amoenus*).

White-footed Mouse (*Peromyscus leucopus*), Masked Shrew (*Sorex cinereus*), and Short-tailed Shrew (*Blarina brevicauda*) were the most common small mammals, cumulatively accounting for 80% of the 637 mammal captures (Table 2). Captures of these species were more evenly distributed throughout the year than those of amphibians, with peak abundances in May or June (Fig. 4).

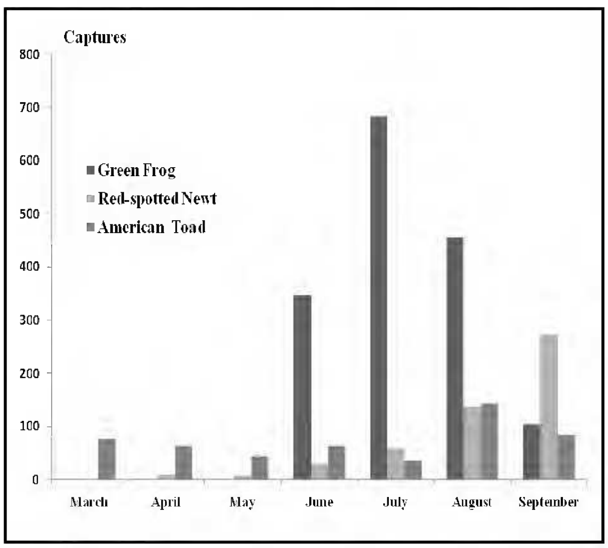

Fig. 3. Relative abundance of the three most commonly captured amphibians from March-September 2006-2008 in pitfall traps at three forest locations in Franklin County, Virginia.

DISCUSSION

The numbers of small vertebrates in this study were heavily weighted toward dispersing juvenile amphibians, particularly Green Frogs, but to a lesser extent Red-spotted Newts and American Toads. We observed that after a period with few or no captures during a period of dry weather, many more Green Frogs were caught after a rain event, particularly a heavy one (> 2.5 cm). Captures tapered off in subsequent days as humidity levels dropped and Green Frogs were perhaps confined to moist refugia. While adult Green Frogs generally stay close to pond margins, recently metamorphosed frogs disperse far from their natal ponds (Martof, 1953; Schroeder, 1976). Martof (1953) found the dispersal of Green Frog metamorphs to be highly correlated with precipitation and high humidity levels on the forest floor, observations confirmed in our

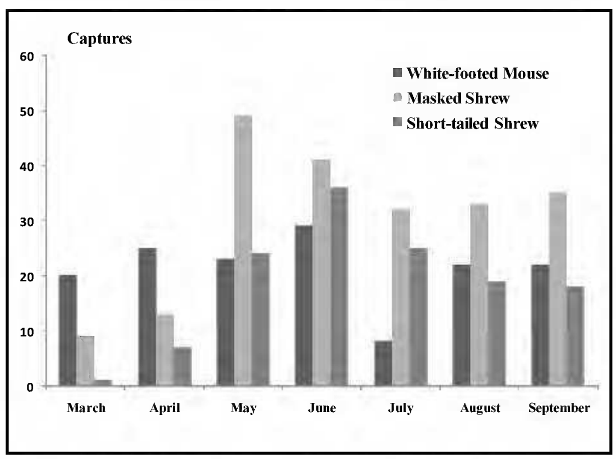

Fig. 4. Relative abundance of the three most commonly captured small mammals from March-September 2006-2008 in pitfall traps at three forest locations in Franklin County, Virginia.

Table 2. Total pitfall trap captures per coarse woody debris (CWD) treatment over three locations (blocks) and three sampling years at forest locations in Franklin County, Virginia.

Group / Species	**CWD Removed (0X)**	**Control (1X)**	**Double CWD (2X)**
All species	**1280**	**1433**	**924**
Amphibians	**1042**	**1194**	**684**
Anaxyrus (= *Bufo*) *americanus*	195	179	132
Ambystoma maculatum	8	7	6
Desmognathus fuscus	8	1	6
Desmognathus monticola	1	0	0
Eurycea cirrigera	6	7	2
Gastrophryne carolinensis	1	0	0
Hemidactylium scutatum	0	0	2
Hyla chrysoscelis	2	3	1
Lithobates (= *Rana*) *catesbeianus*	0	0	1
Lithobates (= *Rana*) *clamitans*	536	758	294
Lithobates (= *Rana*) *palustris*	56	55	17
Lithobates (= *Rana*) *sylvaticus*	6	4	2
Notophthalmus viridescens	179	153	191
Plethodon cylindraceus	19	9	10
Pseudacris crucifer	2	3	4
Pseudotriton montanus	1	1	0
Pseudotriton ruber	22	14	16
Reptiles	**22**	**31**	**27**
Carphophis amoenus	3	3	9
Diadophis punctatus	0	2	0
Pantherophis (= *Elaphe*) *alleghaniensis*	1	1	0
Plestiodon (= *Eumeces*) *fasciatus*	14	12	11
Sceloporus undulatus	1	3	2
Scincella lateralis	1	4	0
Storeria occipitomaculata	1	2	2
Terrapene carolina	1	2	1
Thamnophis sirtalis	0	2	1
Virginia valeriae	0	0	1
Mammals	**216**	**208**	**213**
Blarina brevicauda	52	44	40
Condylura cristata	0	0	1
Didelphis virginiana	1	2	2
Microtus pennsylvanicus	0	0	1
Myodes (= *Clethrionomys*) *gapperi*	14	11	11
Napaeozapus insignis	9	5	7
Ochrotomys nuttalli	4	4	5
Peromyscus leucopus	41	50	63
Scalopus aquaticus	0	0	2
Sorex cinereus	85	78	56
Sorex fumeus	10	14	25

study. Timm et al. (2007) found that precipitation and temperature were important variables in the departure of juvenile amphibians from breeding sites.

The larger number of Green Frog captures in 2006 compared to the other two years of this study may be explained by the higher rainfall during that year, particularly from late June to early August which was the peak period for Green Frog dispersal in the study area. Green Frog populations have been known to undergo substantial fluctuations in local abundance (Hecnar & M'Closkey, 1997). The small mammal capture rate was also related to rainfall, as has been observed in other studies (Gentry et al., 1966). It has been suggested that when rain dampens the forest floor, it allows rodents to move while making the least amount of noise possible to avoid detection by predators (Fitzgerald & Wolff, 1988).

Captures of many species varied among months. Green Frog captures increased dramatically in June and peaked in July, coinciding with the peak dispersal of juveniles, while Red-spotted Newt captures peaked in September, when large numbers of very small (<3 cm), recently dispersed juveniles were captured. Captures of American Toads tended to be highest in August and September. Timm et al. (2007) also observed that Julian date varied for dispersal of juvenile amphibian species. In our study, captures of Five-lined Skinks and Eastern Fence Lizards also increased during the summer, coinciding with the hatching of juveniles.

No significant differences were observed among CWD treatments despite the fact that CWD is thought to be an important habitat element for small vertebrates in forests (Loeb, 1999; McKenny et al., 2006). Several other recent studies have also failed to detect a response in small vertebrate captures to CWD (Greenberg et al., 2006; Moseley et al., 2008; Owens et al., 2008; Matthews et al., 2009; Davis et al., 2010). Davis et al. (2010) suggested that a lack of response on Coastal Plain sites may be due to a large number of species adept at burrowing into sandy soils of that physiographic province, perhaps an adaptation to low levels of woody debris due to periodic fires. This does not explain, however, studies showing a lack of response to CWD manipulation by small vertebrates in forests in the Piedmont and Mountain provinces of the southeastern United States.

The numerical dominance of captures in our study by dispersing juvenile amphibians may partially explain the lack of overall response to CWD manipulation treatments because they tend to disperse during rain events and may not rely on CWD for cover. In fact, CWD could perhaps deflect small amphibians away from the pitfall arrays, resulting in more captures in the pitfall-drift fence arrays without CWD. In addition, although our study design avoided bias with distance to nearby streams, it did not remove bias with distance to nearby ponds. At the Moonshine Creek site, the plot closest to the pond was the 1X treatment and this plot had the largest number of Green Frog captures. Likewise, the plot closest to Chapman pond was the 0X treatment and this plot had the largest number of Red-spotted Newt captures.

Apart from dispersing juvenile amphibians, however, there were no significant differences in captures among the CWD treatments for vertebrate species whose captures were not dominated by dispersing juveniles and whose movements would not likely be deterred by CWD, such as small mammals and small snakes. Small mammals often use CWD as runways to avoid detection by predators and facilitate movement (Wolff & Hurlbutt, 1982; Barnum et al, 1992; McCay, 2000).

CONCLUSIONS

We report the relative abundances of small vertebrates in hardwood-white pine forests in the upper Piedmont and dominated by dispersing juvenile amphibians in summer. A strong relationship between the activity of small vertebrates and rainfall was observed. Although known to be important for many small vertebrate species, no significant difference was detected in the number of captures for any small vertebrate group or individual species to the amount of fallen stems or branches within the vicinity of trapping locations.

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